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HEAT AND MASS TRANSFER OF MHD FOR AN UNSTEADY VISCOUS OSCILLATORY FLOW

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ABSTRACT

Magnetohydrodynamic (MHD) studies on chemical reaction concepts, with heat and mass transfer, were presented. Unsteady viscous at the two-dimensional motion of oscillatory flow is considered. Transverse magnetic on a field known to have an influence on pressure gradient at non-dimensional parameters were closely studied and a technique point was carried out. Hartmann number, Grashof, Prandtl, Schmidt numbers and diffusivity ratio effect on the velocity profile and temperature profile overheat and mass transfer of MHD flow. Graphically presentation shows velocity gradient change in the Hartmann number, suction/injection, Grashof, and Prandtl. For Schmidt numbers velocity profile increase on heat and mass transfer. Diffusivity ratio also leads to change velocity and temperature profile.

Keywords: Heat, Mass, MHD, Porous plate, Velocity, Temperature, Thermal radiation.

INTRODUCTION

Newtonian, Non-Newtonian, Plastic, and Ideal are fluids types. Non-Newtonian fluids, which do not obey the Newton law of viscosity was considered for this study. Non-Newtonian fluids are important in technological applications and appropriate many industrial manufacturing processes such as in the drilling of oil and gas wells, petroleum industries, polymer, pumps as well as accelerators, power generators and flow of meters, etc. From many engineering problems, MHD analysis is sometimes required. The study MHD has given a remarkable interest for its applications. The study of liquid metals, electrolytes, and ionized gases on convection-free flow is also important.

The phenomena MHD is encountered from geophysical interactions of fluid and magnetic fields conducted. Where conduction occurs electrically during fluid flow rotation of magnetic field and makes the need studies of MHD important in geophysical problems. MHD was first introduced by Hannes Alfven in1942 a letter sent to Nature. And leads to many research carried out on various condition surrounding MHD.

The porous medium magnetic flow between two infinite parallel plates was considered due production of currents applications in such conditions. Thereby leading MHD designing of electrical generating systems and production electric generators devices among other Hassanien and Mansour (1990). MHD Poiseuille flow at steady state due occurs between two infinite parallel porous plates and so was studied by Alfred in 2013, with the resulting inclination of magnetic field been examined. Oscillatory Poiseuille flow at steady was considered by Alfred. The work was later extended where unsteady was considered on Poiseuille oscillatory condition of MHD flow between two infinite parallel porous plates in a magnetic field.

One of the most important aspects is the chemical reaction between the fluid flow is studied on MHD due to its involvement on ionic molecular structure substance that discharged during rearrangement process and also nuclear reaction or physical change from one form to others (Umavathi, 2014). There are two forms of reactions which are homogeneous reaction and heterogeneous reaction where the uniform phase of the flow occurs throughout and on which particular region takes place both with or within the boundary phase (Umavathi, 2014).

The occurrence of heat transfer due to the chemical reaction was studied with most significance enfaces no scientists and engineers due to the universal needs of the area with incidence such as branches Satya *et al* (2015), "The phenomenon plays an insignificant role on industry chemical reaction, power and cooling industry used for dying the evaporation, energy transfer from the cooling tower and the desert cooler the flow, etc.". The increasing number of industrial applications is high on heat and mass transfer of MHD flow through the combination of chemical reaction Umavathi (2014). MHD oscillatory flow affects chemical reactions together with a heat source over an irregular channel. Sherwood number and chemical reaction parameter where varies on the assumption of MHD flow is through an irregular channel. The results show a decrease in velocity profiles and concentration means there is an increase in chemical reaction Satya *et al* (2015)

Many research works are conducted on MHD such as the likes of Debnath, in1975; Raptis, in 1983 and Singh, works are presented in 1983. The present works on MHD today are the result of open up research works conducted by some pioneer's notable people like (Alfven, 1942; Cowling, 1957; Ferraro and Pulmpton, 1966) that make it possible (Mubarak, Agaie, Joseph, Daniel, & Ayuba, 2017).

The complexity in electromagnetism is a combination of hydrodynamics and magnetic properties such as salt or electrolytes, plasma materials, and metal at the liquid stage on an electrical fluid conductor, Agaie, Ndayawo, Usman, & Abdullahi, (2020). Solar physics is an important aspect of flow problems that need to study due to rotation while dealing with MHD fluids which led to the development of sunspot, solar cycle, and stars rotating structure of magnetic (Mubarak, Agaie, Joseph, Daniel, & Ayuba).

The interiors and magnetic of fluid fields are known during astronomical bodies to possess. For any rotation, a lot of changes take place in the process which shows that there is the possibility of hydromagnetic analysis of MHD which is an important research tool. The theory of rotating begins on the fluid in general and follows by the development of Cosmic and Geophysical science in last with its application (Agaie, Ndayawo, Usman, & Abdullahi, 2020).

The density direction and forces of an electric field are known to be transverse in component because of the balance on current flows. Magnetic field applications are adequately funded in large strength that leads to Ohm's law and so modifies by inclusion Hall current. Magnetic forces emphasize through the sideways of drifting and

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are freely charging (Mubarak, Agaie, Joseph, Daniel, & Ayuba).
The magnetic field overlooks a given strong point when the amount of electrons density is known to be minor. The flow pattern is responsible for changes in an ionized gas. Potential difference development is an addition in-between the two opposite surfaces on a conductor. Hall current was discovered by Edwin Herbert Hall in 1879 during his doctoral degree work, submitted to the University of Johns Hopkins in Baltimore, Maryland, USA (Acharya *et al.*, 2001; Ahmed and Kalita, 2011; Kinyanjui *et al.*; Pop, 1971). The Effect of Hall current on both the electric and magnetic fields is always found perpendicular to the current is induced.
Fluid forces take place at the constant magnetic field in the electrical current, created by the motion that induces conduction, which leads to the design of MHD generators. With these, there is a need for further research on many areas (Kuiry and Bahadur, 2014)
Fluid conduction in a pipeline is at steady motion under transverse magnetic fields for an electrical generation was studied by Shercliff (1956); pipeline fluid flow is not on usual, but a channel fluid flow, which improves its viability was researched by using separation of variables method on MHD flow with a periodic pressure gradient (Drake, 1965). Laplace transformation method was used on electrically conduction fluid flow on laminar conditions passing through a channel with periodic pressure gradient to obtain the influence of transverse magnetic field (Singh and Ram, 1978).
On heat and mass transfer research was carried out on the fluid flow effect through porous media (Ram *et al.*, 1984). Flow on porous medium in between two infinite plates where magnetic flow is known to be parallel plates at steady-state condition was studied by Hassanien and Mansour, (1990). Poiseuille flow between infinite parallels porous plates, an inclined magnetic field considered on MHD was studied by Manyonge and Wambua (2013). Also, an inclined magnetic field effect considered on a steady flow of Poiseuille was studied by Kuiry and Bahadur (2014).
For an improvement of the work on MHD Poiseuille, the unsteady flow was considered by Idowu and Olabode (2014). Unsteady flow oscillatory MHD under mixed convection for generation of heat on the second-grade fluid in a porous channel was discussed by Gital and Abdulhameed, (2013). Channel porous injection/suction walls were assumed to be unsteady oscillatory flow on which heat transfer through the horizontal composite medium was observed (Umavathi *et al.*, 2009).
Industrial developments are better in performance and lesser in the cost to micro heat exchangers, such as micromixers. Micro electro-mechanical devices have a thermal cooling system that is high while, micro-pumps have chemical sciences and engineering fields system. Entropy also utilized thermal devices energy that is based on micropolar nanofluid flow. A research was conducted on an inclined channel with impacts over viscous dissipation and mixed convection of temperature jump and velocity slip numerically. It was established that entropy can affect the generation aspect for radiative, viscous dissipation, and magnetism on heat flux (Roja, Gireesha, & Prasannakumara, 2020).
An accurate analysis of MHD can be improved through solution methods to have a good contribution to a possible implementation of real-life problems. The Reynolds exponential model was used for a steady incompressible flow of MHD through a vertically stretched porous sheet and viscosity-dependent temperature in the mathematically model formulation. The development of a linearized based spectral local linearization method (SLLM) algorithm, was on nonlinear functions on a smooth invariant. SLLM impressive performance with accelerating solutions equations convergence with high accuracy has been reported graphically. The temperature, velocity, and concentration distribution's effect on skin friction, the Nusselt number, and Sherwood number were discussed in detail (Shahid, Huang, Khalique, & Bhatti, 2020).
Effect thermal and chemical properties on three dimensional steady MHD at a laminar flow on boundary layer was investigated were horizontal stretching sheet toward Casson nanofluid flow. The governing equation on Partial Differential Equation (PDEs) was converted to a set of nonlinear Ordinary Differential Equations (ODEs) using similarity transformations. Casson nano parameter is used to control and minimize the magnetic field flow friction factor for getting closer to infinity as in the case of Newtonian. The published results agree with earlier obtain results as presented by some authors for limited cases, research can be carried out to validating present results. For accuracy, the chosen solution method is important for the formation of a non-dimensional parameter to the governing equations.

MATERIALS AND METHODS

Unsteady MHD with free convective heat and mass transfer over temperature and velocity profile is assumed to determine the effect of two immiscible fluid flows in a horizontal channel, in this research the main concern is to study the interaction of fluid conducting electrical and the electromagnetic fields. The porous region is assumed at the upper channel, while a clean region in the lower and are bounded by two infinite horizontal plates that are parallel, X and Z. The regions are given as $y[0,h]$ and $y[-h,0]$ representing Region I (Porous) and Region II (Clean) on the geometry as depicted below.
The walls are boundary by $Cw_i, Tw_i \ \rho_i, \mu_i \ k_i$ and D_i known has concentration, temperature concentration density, dynamic viscosity thermal conductivity, and thermal diffusivity of the regions respectively.
The occurrences of heat transfer are due to the difference in fluid temperature of both plates where Tw1 is greater than Tw2 and the direction of gravitational force that courses decrease in density. The flow is assumed to be fully developed with functional variables are space y' and time t'. Subsequently, the surface binding is infinite with a small Reynold number for the magnetic field. The physical diagram representation of the problem is presented in Figure 1.

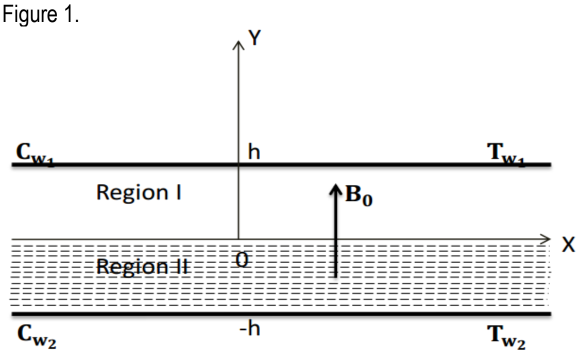

Figure 1: Flow channel with Regions
Therefore, the assumed problem governing equations will be given as follow:

$$\frac{\partial v_j'}{\partial y'}=0 \quad (1)$$

$$\rho_j\left(\frac{\partial u_j'}{\partial t'}+v_1'\frac{\partial u_j'}{\partial y'}\right)= \mu_j\frac{\partial^2 u_j'}{\partial y'^2}-\frac{\partial P'}{\partial x'}-\sigma B_0^2 u_j'+\rho_j g\beta_{f_j}(T_j'-T_{w_j}')+\rho_j g\beta_{c_1}^*(C_j'-C_{w_j}') \quad (2)$$

$$\rho_j C_p\left(\frac{\partial T_j'}{\partial t'}+v_j'\frac{\partial T_j'}{\partial y'}\right)=k_j\frac{\partial^2 T_j'}{\partial y'^2}-\frac{\partial q_r}{\partial y'} \quad (3)$$

$$\frac{\partial C_j'}{\partial t'}+v_j'\frac{\partial C_j'}{\partial y'}=D_j\frac{\partial^2 C_j'}{\partial y'^2} \quad (4)$$

where $j=1,2$ for porous and clear regions (Agaie, Ndayawo, Usman, & Abdullahi, 2020)

To obtain mass and heat flow transfer effect, the method of regular perturbation was used analytically to solve the governing equations, for temperature, concentration, and velocity.

Following boundary and interface conditions are assumed on the no-slip conditions

For both regions velocity profile at the boundary and interface conditions are:

$$U_1'(h)=0,\quad U_2'(-h)=0,\quad U_1'(0)=U_2'(0),$$
$$\mu_1\frac{\partial U_1'}{\partial y'}=\mu_2\frac{\partial U_2'}{\partial y'}\ at\ y'=0 \quad (5)$$

For both fluids regions temperature profile at the boundary and interface conditions are:

$$T_1'(h)=T_{w1}',U_2'(-h)=T_{w2}',T_1'(0)= T_2'(0),k_1\frac{\partial T_1'}{\partial y'}=k_2\frac{\partial T_2'}{\partial y'}\ at\ y'=0 \quad (6)$$

For fluid concentration the boundary and interface conditions are given as:

$$C_1'(h)=C_{w_1}',C_2'(-h)=C_{w_2}',C_1'(0)= C_2'(0),\ D_1\frac{\partial T_1'}{\partial y'}=D_2\frac{\partial T_2'}{\partial y'}\ at\ y'=0 \quad (7)$$

Method of Solution

Let us assumed the following $v_j'=v',\ for\ \ j=1,2$, for all cross-sectional so velocity is written as $v_j'=v_0(1+\varepsilon Ae^{i\omega t})$.

Therefore, v_j' will not vary under y' in equation (1) with the time function for both j=1 and 2. Where ω,ε and A are frequency parameters, small positive constant and real positive constant such that $\varepsilon A<<1$. It was assumed that the velocity transpiration varies periodically with respect to time around a non-zero constant mean (Sturat, 1955). The transpiration recovered is constant when $\varepsilon A=0$.

The governing equations are then transformed using dimensionless quantities together with the boundary and interface conditions into non-dimensional form at h=1

The resulting equations are then expanded before separated into periodic and non-periodic parts using perturbation term ε. By assuming ε<<1 the following dimensionless equations are obtained for velocity, temperature, and concentration of both regions

$$U_j(y,t)=U_{j0}(y)+\varepsilon e^{i\omega t}U_{j1}(y),$$
$$\theta_j(y,t)=\theta_{j0}(y)+\varepsilon e^{i\omega t}\theta_{j1}(y),$$
$$C_j(y,t)=C_{j0}(y)+\varepsilon e^{i\omega t}C_{j1}(y) \quad (8)$$

We then differentiate the functions with respect to t and y respectively and substitute the governing equations of the regions, where ε^2 is neglected because it tends to zero, we get:

Region I

Velocity profile for period and non-periodic parts:

$$\varepsilon^0:\ U_{10}''-U_{10}'-(M^2+K^2)U_{10}=-P-G_r\theta_{10}-G_cC_{10} \quad (9)$$

$$\varepsilon^1:\ U_{11}''-U_{11}'-(M^2+K^2+i\omega)U_{11}=U_{10}'-G_r\theta_{11}-G_cC_{11} \quad (10)$$

Temperature for the period and non-periodic parts:

$$\varepsilon^0:\theta_{10}''-\Pr\theta_{10}'-F\theta_{10}=0 \quad (11)$$

$$\varepsilon^1:\theta_{11}''-\Pr\theta_{11}'-(i\omega\Pr+F)\theta_{11}=\Pr\theta_{10}' \quad (12)$$

Concentration for the period and non-periodic parts:

$$\varepsilon^0:C_{10}''-ScC_{10}'-K_cC_{10}=0 \quad (13)$$

$$\varepsilon^1:C_{11}''-ScC_{11}'-(i\omega Sc+K_c)C_{11}=ScC_{10}' \quad (14)$$

Region II

Velocity profile for period and non-periodic parts:

$$\varepsilon^0:\ U_{20}''-\frac{U_{20}'}{\alpha\xi}-\frac{U_{10}}{\alpha}=-\frac{P}{\alpha}-\frac{G_rm\theta_{20}}{\alpha\xi}-\frac{G_c\eta C_{20}}{\alpha\xi} \quad (15)$$

$$\varepsilon^1:\ U_{21}''-\frac{U_{21}'}{\alpha\xi}-(\frac{M^2\xi+i\omega}{\alpha\xi})U_{21}=\frac{U_{20}'}{\alpha\xi}-\frac{G_rm\theta_{21}}{\alpha\xi}-\frac{G_c\eta C_{11}}{\alpha\xi} \quad (16)$$

Temperature for the period and non-periodic parts:

$$\varepsilon^0:\theta_{20}''-\frac{\Pr\theta_{20}'}{\beta\xi}-\frac{F\theta_{20}}{\beta}=0 \quad (17)$$

$$\varepsilon^1:\theta_{21}''-\frac{\Pr\theta_{21}'}{\beta\xi}-(\frac{i\omega\Pr+F\xi}{\beta\xi})\theta_{21}=\frac{\Pr\theta_{20}'}{\beta\xi} \quad (18)$$

Concentration for the period and non-periodic parts:

$$\varepsilon^0 : C_{20}^{"} - \frac{ScC_{20}}{\gamma} - K_{c2}C_{20} = 0 \quad (19)$$

$$\varepsilon^1 : C_{21}^{"} - \frac{ScC_{21}^{'}}{\gamma} - (\frac{i\omega Sc}{\gamma} + K_{c2})C_{21} = \frac{ScC_{20}^{'}}{\gamma} \quad (20)$$

From equation (15) we have

$$m^2 - P_r m - F = 0$$ where

$$m_1 = \frac{Pr + \sqrt{Pr^2 + 4F}}{2}, \quad m_2 = \frac{Pr + \sqrt{Pr^2 + 4F}}{2}$$

Therefore

$$\theta_{10}(y) = C_1 e^{m_1 y} + C_2 e^{m_2 y} \quad (21)$$

$$m^2 - Scm - K_{c1} = 0$$

$$m_3 = \frac{Sc + \sqrt{Sc^2 + 4Kc_1}}{2}, \quad \& \ m_4 = \frac{Sc - \sqrt{Sc^2 + 4Kc_1}}{2}$$

$$C_{10} = C_3 e^{m_3 y} + C_4 e^{m_4 y} \quad (22)$$

Solving (14)

$$U_{10}^{"} - U_{10}^{'} - (M^2 + K^2)U_{10} = -P - G_r\theta_{10} - G_c C_{10}$$

$$\Rightarrow m^2 - m - V_3 =$$

$$-P - Gr(C_1 e^{m_1 y} + C_2 e^{m_2 y}) - Gc(C_3 e^{m_3 y} + C_4 e^{m_4 y})$$

$$\Rightarrow U_{10\,Complementary} = C_5 e^{m_5 y} + C_6 e^{m_6 y} \quad (23)$$

The particular solution is assumed to be:

$$U_{10_{Particular}} = K_1 + K_2 e^{m_1 y} + K_3 e^{m_2 y} + K_4 e^{m_3 y} + K_5 e^{m_4 y} \quad (24)$$

The original equation to solve for K's my differentiating and substituting in get the following general solution

$$U_{10} = C_5 e^{m_5 y} + C_6 e^{m_6 y} + K_1 + K_2 e^{m_1 y} + K_3 e^{m_2 y} + K_4 e^{m_3 y} + K_5 e^{m_4 y} \quad (25)$$

Solving (16)

$$\theta_{11}^{"} - \Pr\theta_{11}^{'} - (i\omega\Pr + F)\theta_{11} = \Pr\theta_{10}^{'}$$

$$\Rightarrow m^2 - m\Pr - V_1 = \Pr\theta_{10}^{'} \quad (26)$$

Substituting equation (25) into (30) and solving the homogeneous part

$$\theta_{11_{Complementary}} = C_7 e^{m_7 y} + C_8 e^{m_8 y} \quad (27)$$

Now let

$$\theta_{11_{Particular}} = K_6 e^{m_1 y} + K_7 e^{m_2 y} \quad (28)$$

Differentiating and substituting into the original equation to solve for unknown expressions, we get the following general solution

$$\theta_{11} = C_7 e^{m_7 y} + C_8 e^{m_8 y} + K_6 e^{m_1 y} + K_7 e^{m_2 y}$$

$$\theta_{20}^{"} - \frac{\Pr\theta_{20}^{'}}{\beta\xi} - \frac{F\theta_{20}}{\beta} = 0, m^2 - \frac{\Pr}{\beta\xi}m - \frac{F}{\beta} = 0,$$

$$\varepsilon^1 : \theta_{21}^{"} - \frac{\Pr\theta_{21}^{'}}{\beta\xi} - (\frac{i\,\omega\Pr + F\,\xi}{\beta\xi})\theta_{21} = \frac{\Pr\theta_{20}^{'}}{\beta\xi}$$

Nusselt Number: The rates of heat transfer in the upper and lower plates are given as follows:

$$Nu(U) = \left[\frac{\partial\theta_{10}}{\partial y}\right]_{y=1} + \varepsilon e^{iwt}\left[\frac{\partial\theta_{10}}{\partial y}\right]_{y=1}$$

$$= c_1 m_1 e^{m1} + c_2 m_2 e^{m2} \varepsilon e^{iwt}(c_7 m_7 e^{m7} + c_8 m_8 e^{m8} + k_6 m_1 e^{m1} + k_7 m_2 e^{m2})$$

$$Nu(L) = \left[\frac{\partial\theta_{20}}{\partial y}\right]_{y=-1} + \varepsilon e^{iwt}\left[\frac{\partial\theta_{21}}{\partial y}\right]_{y=-1}$$

$$= c_{13} m_{13} e^{-m13} + c_{14} m_{14} e^{-m14} \varepsilon e^{iwt}(c_{19} m_{19} e^{-m19} + c_{20} m_{20} e^{-m20} + k_{25} m_{13} e^{-m13} + k_{26} m_{14} e^{-m14})$$

Sherwood Number: The ratio of convective to diffusive mass transfer at the upper and lower plates is given as follows:

$$Sh(U) = \left[\frac{\partial C_{10}}{\partial y}\right]_{y=1} + \varepsilon e^{iwt}\left[\frac{\partial C_{11}}{\partial y}\right]_{y=1}$$

$$= c_3 m_3 e^{m3} + c_4 m_4 e^{m4} \varepsilon e^{iwt}(c_9 m_9 e^{m9} + c_{10} m_{10} e^{m10} + k_8 m_3 e^{m3} + k_9 m_4 e^{m4})$$

$$Sh(L) = \left[\frac{\partial C_{20}}{\partial y}\right]_{y=-1} + \varepsilon e^{iwt}\left[\frac{\partial C_{21}}{\partial y}\right]_{y=-1}$$

$$= c_{15} m_{15} e^{-m15} + c_{16} m_{16} e^{-m16} \varepsilon e^{iwt}(c_{21} m_{21} e^{-m21} + c_{22} m_{22} e^{-m22} + k_{27} m_{15} e^{-m15} + k_{28} m_{16} e^{-m16})$$

RESULTS AND DISCUSSION

To evaluate the analytical solutions obtained by the regular perturbation method taken epsilon as the perturbation parameter the results are graphical representations. This is to explore the important features of the governing parameters in the velocity profile, temperature profile, and concentration profile. Throughout the computation, we employ constant values to be the following governing parameters Gr=5, Gc=5, Pr=1, α=1, β=1, γ=1, ξ=1, η=1, Sc=0.78, F=3, K=2, M=1, P=1, Kc=0, except the ones that are varying in the respective figures. The graphs depicting relationships between various flow parameters.

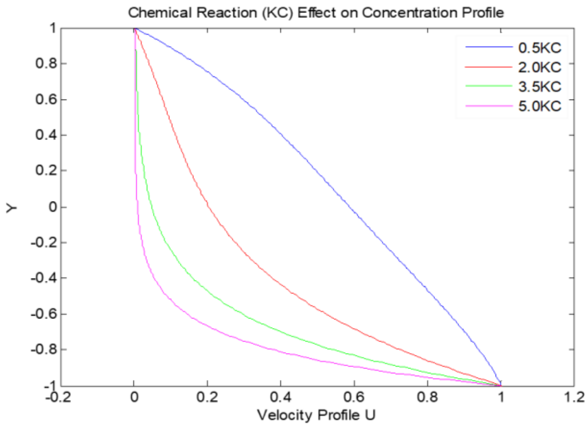

Figure 2: Chemical Reaction of Porous Medium Kc on flow Concentration

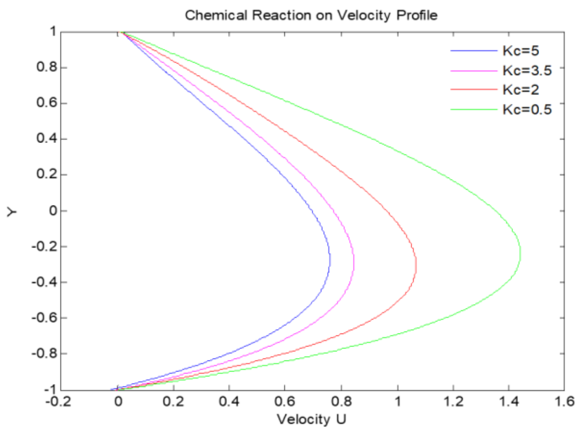

Figure 3: Chemical Reaction Parameter (Kc) on Velocity Profile

The chemical reaction parameter (Kc) effect is presented in figure 2 and figure 3 and shows an increase in the parameter, which leads to a decrease in both the concentration and velocity profiles. It was observed that the result has similarity to the result represented by (Umavathi *et al.*, 2010).

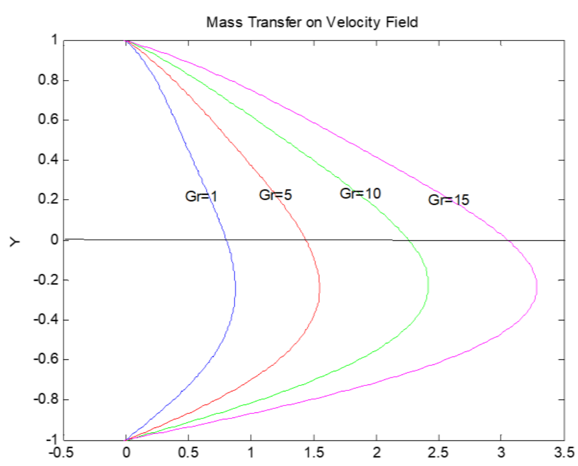

Figure 4 Effect of Grashof Number (Gr) for Mass Transfer on Velocity Field

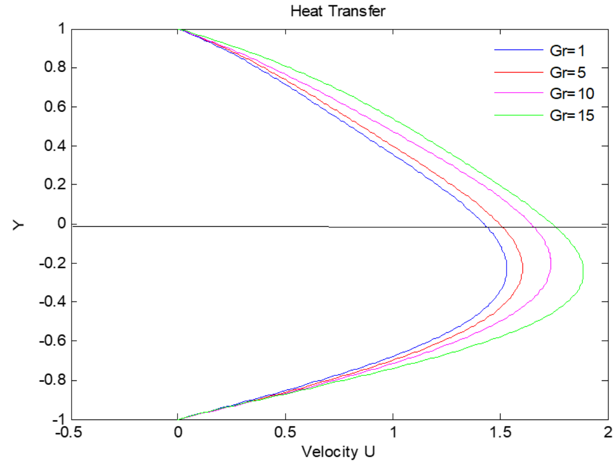

Figure 5 Effect of Grashof Number (Gr) for Heat Transfer on Velocity Field

An increase in Grashof number is observed to have leads to increase velocity profiles on both heat and mass transfer simulation as shown in Figures 4 and 5 respectively. The effect of all flow parameters is the same as early reported by (Mubarak, *et al.*, 2017 and Zhang, *et al*, 2020). This means an increase in buoyancy force over viscous force on both regions with almost equal strength. However, the Grashof number for mass transfer increases the velocity more than the Grashof number for mass transfer. This means that buoyancy force increases over the viscous force for both regions with almost equal strength. Both there is an increase in mass transfer over heat transfer on velocity profile for an increase on Grashof number.

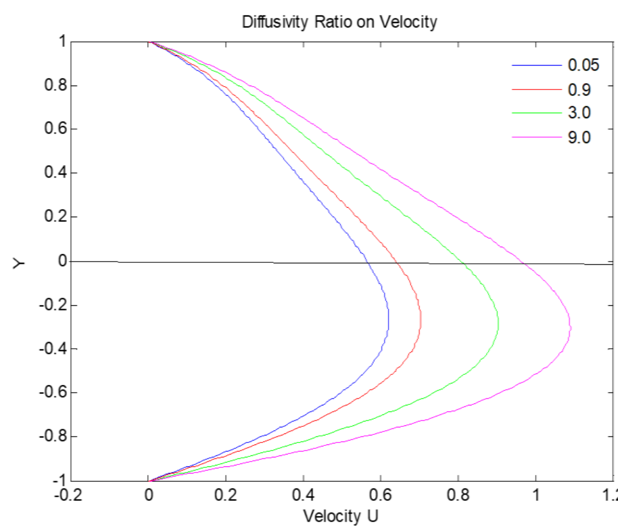

Figure 6: Diffusion Ratio Effect on Velocity Profile at both Region

From figure 6 molecular diffusivity ratio is presented on the velocity profile of momentum over molecular diffusion on both regions has been observed. While the velocity profile tends to the maximum as K increases. However, the velocity drags in Region I is very large for a large value of K, a similar result was observed by (Umavathi, *et al.*, 2010) for porous media sandwiched between viscous fluids.

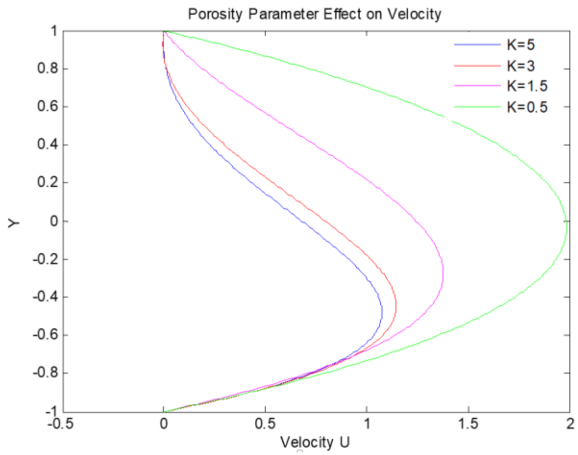

Figure 7: Porosity Parameter Effect on Velocity Profile

In figure 7 porosity parameter is varied on velocity profile in which it was observed decrease on the permeability of porous medium leads to increase on velocity profile at the region I and in region II the effect is less. In figure 8 increase of Grashor number leads to an increase in velocity profile variation on both Region.

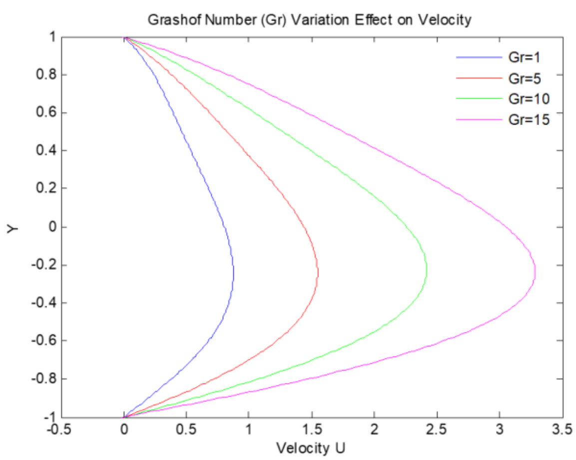

Figure 8: The Effect of Grashor Number (Gr) on Variation of Velocity Profile

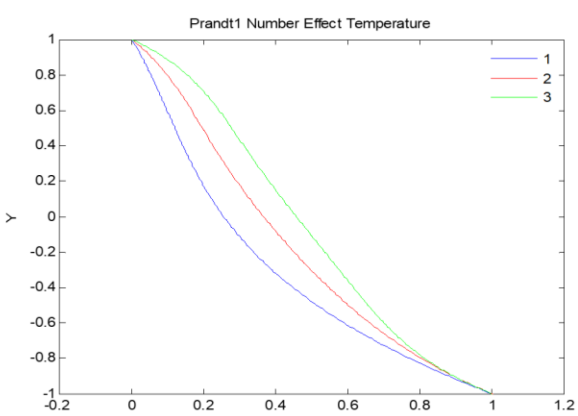

Figure 9: Effect of Prandtl 1 Number on the temperature profile

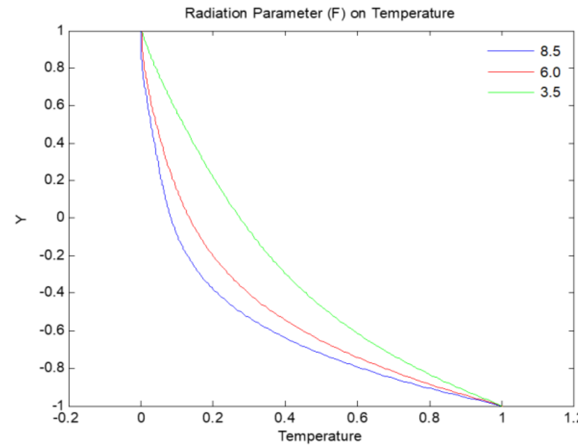

Figure 10: Effect of Radiation Parameter (F) on Temperature Profile

In figure 8, the effect of Grashor Number (Gr) on variation shows an increase of velocity profile for any increase on Gr. The effect of Prandtl number (Pr) on temperature is shown in figure 9, there is a significant change on the graph curve for an increase in Prandtl number. The radiation parameter (F) on the temperature profile is presented in figure 10. It is observed that an increase in both the Prandtl number and Radiation parameter leads to an increase in the temperature profile.

Conclusion

From the graphs presented it was observed that increase in Grashof number while considering heat and mass transfer affect velocity profile, which is also affected by Prandtl number. Chemical results in a decrease in the velocity profile for an increase in the coefficient of a chemical reaction. All flow parameters affected the flow has the study provides and will serve as a guide for industrial uses while dealing with such type of porous medium flow.

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